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Discrete Topographic_and_Orographic Clouds of Mars

By: Jeff Beish
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INTRODUCTION

The Martian atmosphere is very dynamic, exhibiting several types of clouds and hazes easily detected with the aid of color filters and modest-sized telescopes. White water clouds, local yellowish dust clouds, global dust storms, bluish limb hazes, and bright surface *ice-fogs* and frosts have been studied with increased interest over the past three decades. Observations of these meteorological features indicate their behavior and occurrence are most often coupled with the seasonal sublimation and condensation of polar-cap material.

Although the Martian sky appears quite clear, transient bright streaks and oval patches are often observed in its atmosphere that exhibits similar characteristics to clouds and hazes seen in the Earth's atmosphere. Fine dust particles, CO_2 and/or H_2O hazes and ice crystals are regularly observed in Mars' atmosphere using moderate telescopes. From the data gathered by the Mariner and Viking Lander/Orbiter spacecraft, we know that H_2O and CO_2 condensates do exist in the atmosphere of Mars. We are comfortable with the idea that -- what we observe, as bright patches on Mars are in fact atmospheric clouds, fogs, and/or hazes.

In the Earth's atmosphere clouds often form on the windward side of mountains and are classified as Orographic Clouds. Orographic clouds are clouds that develop in response to the forced lifting of air by the earth's topography, such as mountains, and fall into the following general categories:

Conjoined orographic clouds - covers entire mountain, forms on windward side.

Orographic Cumulus fractus – usually covering mountain range, large area of clouds covering both windward and lee sides of mountains.

Orographic Stratocumulus and Altocumulus (wave clouds) – form on the lee side of a mountain.

Pileus (Latin for "skullcap") is a smooth cloud found attached to either a mountaintop or growing cumulus tower.

HOW DISCRETE CLOUDS BEHAVE

*Discrete Topographic_*and*_Orographic Clouds* tend to rotate with the diurnal rotation of the planet. These type phenomena are identified by their location near historically cloudy regions and high mountainous areas. When comparing the historical trends [***Beish et al***, 1986], [***Beish et al,*** 1987], [***Beish*** and ***Parker,*** 1990], and [***Beish*** 1999], it is evident that discrete clouds are more numerous during the northern summer and appears to follow a similar seasonal trend line to both Evening and Morning clouds. As the northern summer begins discrete clouds continue to increase in number and frequency after limb clouds begin decreasing and peek during northern mid-summer. Their number and frequency slowly drops off in late northern summer throughout the remainder of the Martian year.

These discrete white clouds are especially prominent in mountainous regions and volcanoes after rapid

thawing of the North Polar Cap (NPC) begins. By early afternoon, they appear as bright round or oval-shaped individual clouds and at times producing a "Domino Effect" on the Martian disk. Cloud formations can be seen without filters; however, they tend to brighten in blue light. They usually continue to expand and brighten as the planet rotates toward the sunset limb and will brighten violet light, indicating that they also expand upwards by convection. Some of these clouds coalesce with other clouds to form large and bright limb clouds such as the well-known "W-clouds" observed in Tharsis-Amazonis region. A particularly bight section of the W-clouds can be seen over Nix Olympica or Olympus Mons (113°W, 18°N).

Other areas for cloud formations are Nix Tanaica (55°W, 52°N), Nix Cydonia (218°W, 00°N, Arsia Mons (°121W, 19°S), Apollinaris Petera (186°W, 08°S), Ascraeus Mons (104°W, 11°N), Pavonis Mons (112°W, 0°N), and Arisa Mons (120°W, 9°S), and Elysium Mons (212°W, 25°N), and between Tharsis Tholus and Valles Marineris (80°-100°, 04°N). These cloud formations are usually groups of orographic clouds.

Orographic Clouds. On Earth, large dense clouds often form in mountainous regions and hover over the tops of mountains. Air that flows over a mountain forms airwaves on the leeward side of the mountain. In the back of the wave where the air rises, cools and forms smooth elongated clouds. When moist air reaches colder upper altitudes rapidly cooling causes condensation to occur and clouds form. These clouds will linger over mountainous regions for long periods and move around very little in spite of very strong winds. They are referred to as *orographic clouds*. Orographic clouds on Earth are often called almond clouds or lenticular clouds [***Miller*** and ***Thompson***, 1970].

Martian orographic clouds exhibit similar characteristics. Orographic clouds form when the Martian atmosphere rises while flowing up the slopes and over mountains to begin the condensation process. Spacecraft images suggested clouds were lee-wave clouds following the large volcanoes and where found in many regions of the Martian surface. When the gaseous constituents of Mars' atmosphere flow over a mountain and form waves on the leeward side of the mountain, it cools and forms a cloud. Unlike clouds in earth's thicker atmosphere that form into water droplets or a mist, Martian clouds condense directly from vapor to ice particles. The atmospheric pressure on Mars is just too low for liquid water to form.

Topographic Clouds. Dense bluish-white clouds of limited extent populate many areas of Mars during spring and summer after persisting for days in the same general areas. Topographic clouds appear in or near large, deep craters and over great plains and valleys. Three areas; Aram (12°W, 05°S), Edom (345° W, 04°S), and Ophir (65°W, 10°S), are particularly fertile sites for white cloud formation. Another region has been observed to be cloudy during each apparition is the Isidis Regio-Libya-Crocea (275°W, 20°N - 293°W, 00°N) near Syrtis Major. Yellowish clouds, blue-white clouds, and low hazes seem to gravitate into this large depression that lies north of the Tyrrhenum-Hesperia (240°W, 20°S) block and just east of the up-slopes of the Syrtis Major Planum (290°W, 10°N). Wave clouds form on the sheltered side of large obstacles, such as craters, and have very distinct ridges.

Topographic clouds show growth and displacement within a region, especially when near the sunset limb. Often they are called "localized clouds" or "regional discrete clouds" and appear as white patches. They will brighten when observed in blue or blue-green light indicating they are possibly blue or blue-white clouds. Their color can vary; they can become prominent in green or can brighten in yellow light. This led C.F. Capen and the authors to believe they are a combination of water vapor and dust. Topographic clouds are usually long and/or irregular shaped blue or white formations found in bright desert regions. However, they are often observed over portions of dark 'maria' as well. Clouds of this type follow the rotation of the planet and are often observed for several Martian days in the same general

areas. These clouds sometimes form large wedge shapes and may be found in regions where the low plains meet higher elevations, such as the region southeast of the Tharsis bulge.

DISCUSSION

The International Mars Patrol (I.M.P.) has initiated an observing program for intensive investigation into these phenomena and will appeal to all planetary observers using CCD technology to assist us in this important study.

The Hubble Space Telescope (HST) has revealed that these clouds follow a similar trend line or forecast predicted in recent A.L.P.O. meteorological studies of Mars.

Topographic and Orographic Clouds are best detected visually through a light blue (W38A or 80A) and deep blue (W47 and W47B) Wratten filters and may be photographed or imaged in blue or ultraviolet light. They are sometimes observed quite easily in integrated light (non-filters) as well.

New technologies, such as CCD cameras, sophisticated computer hardware and software, and large-aperture planetary telescopes have given rise to a virtual explosion in advanced techniques of studying our Solar System. Never before have we been able to readily detect the delicate wispy Martian Topographic and Orographic Clouds so well as we do now with CCD imaging.

While it is not the purpose to discuss the physics of these clouds we never the less draw certain conclusions from observational evidence. Questions remain that may be answered with high-tech observing techniques by amateur astronomers. There is no reason we cannot at least serve as long termed clouds reporters between scant times of HST observing periods.

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